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Daniel P. Lathrop's Nonlinear Dynamics 雷丹 laboratory

Lorentz force and power dissipation in turbulent flows

Barbara E. Brawn, Nicolas Mujica & Daniel P. Lathrop

Don Martin, Julie Arrighi, Kaveri Joshi, Sandra Penny, Woodrow Shew, Santiago Triana, Daniel Zimmerman, and John Rodgers

Training and Research Experiences in Nonlinear Dynamics
TREND 2004

Our Goals:

- experimental measure of local velocity in sodium flow driven by a known Lorentz force field $\vec{F}_L = \vec{J} \times \vec{B}$

$\vec{J}$ = current density

$\vec{B}$ = magnetic field

- use velocity measurements to yield local power input $P = \vec{u} \cdot \vec{F}$

$\vec{u}$ = local velocity of fluid element

$\vec{F}$ = local force on fluid element

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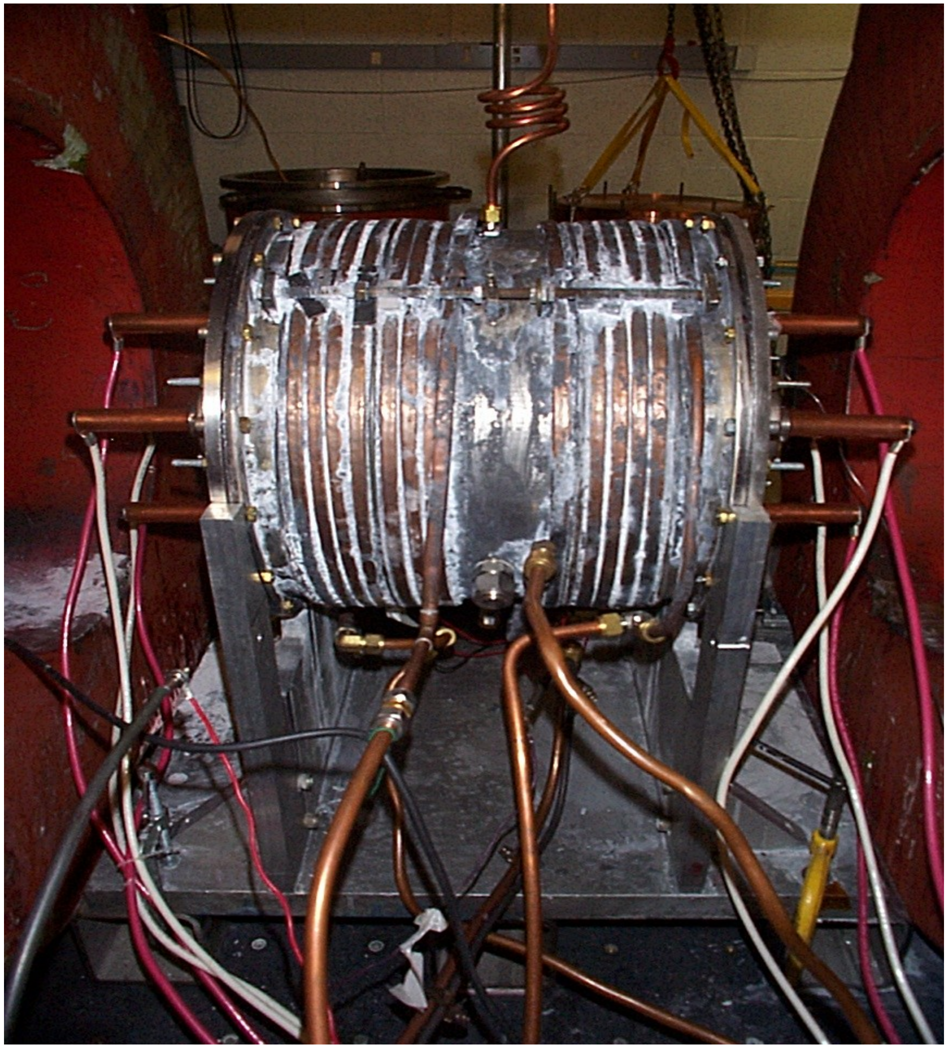

$\vec{F}$ (Experimental Cylinder):

- Produces turbulence in liquid sodium via Lorentz force
- Sodium allows for high Reynolds numbers, no significant heating
- $Re = Dv\rho/\mu \sim 10^4$

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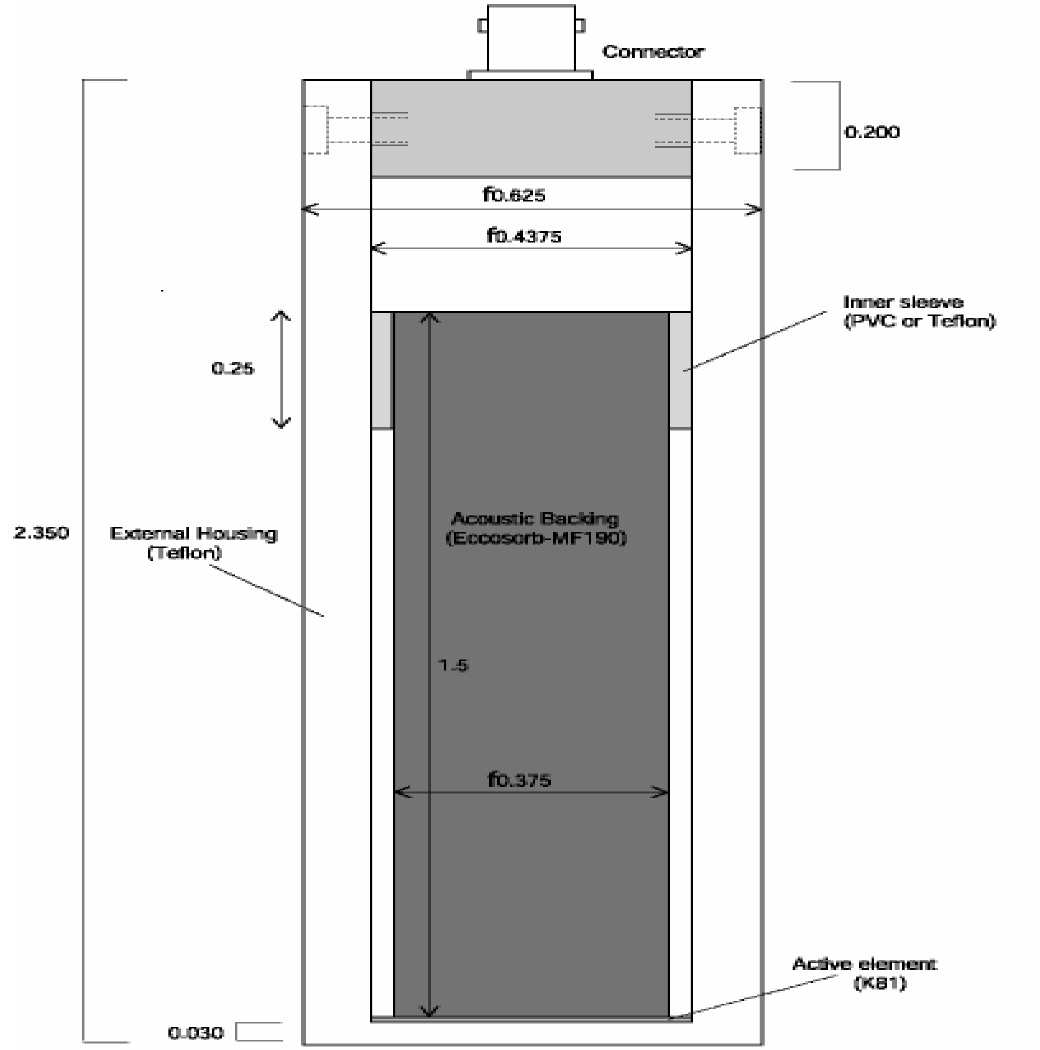
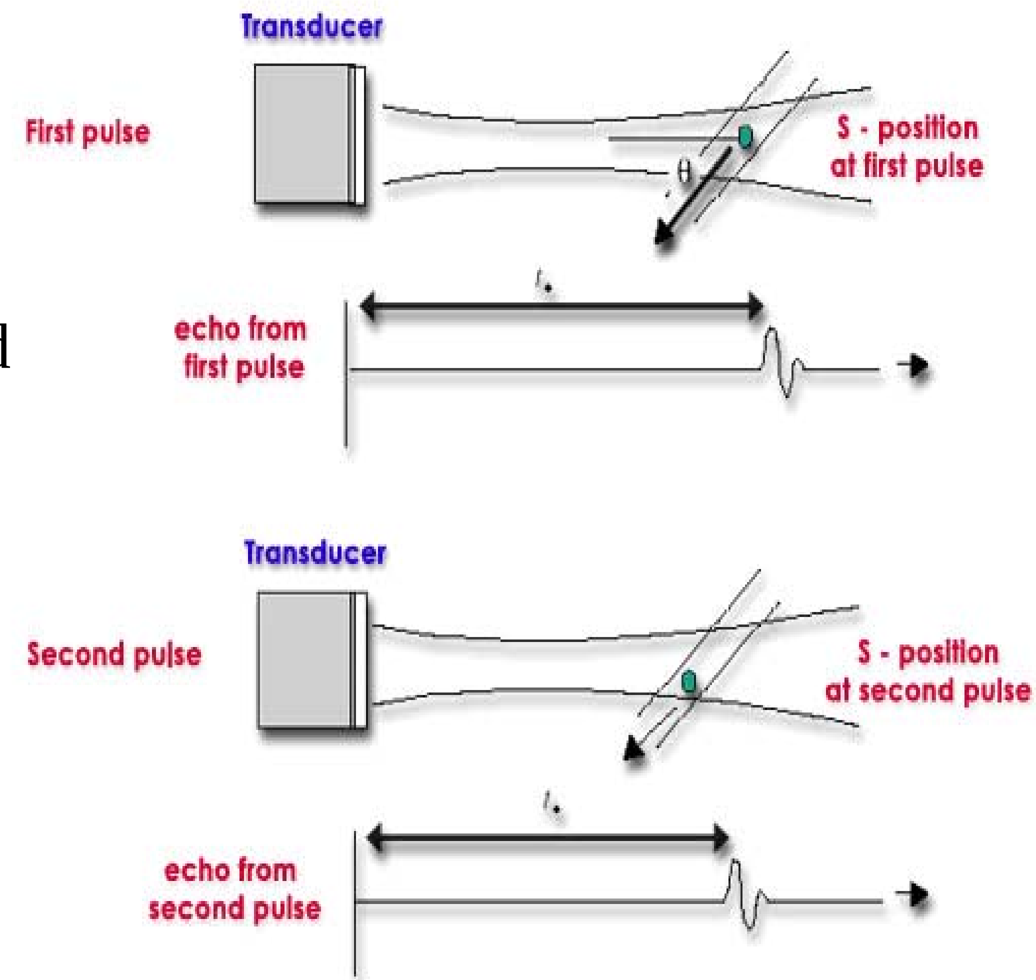
$\vec{u}$ (Ultrasound Velocimetry):

- Transducer emits short US burst, then “listens” for echoes scattered off seed particles

- ***t = 2x/c*** , where ***t*** = time delay, ***x*** = distance of particle from transducer, ***c*** = speed of sound in medium

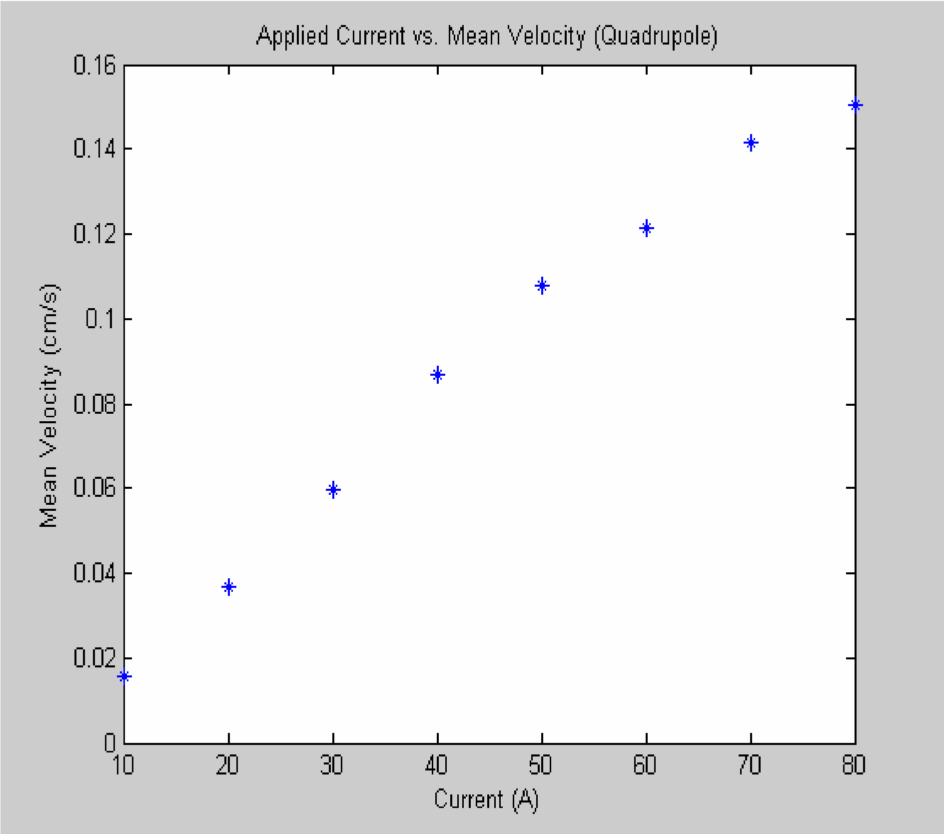


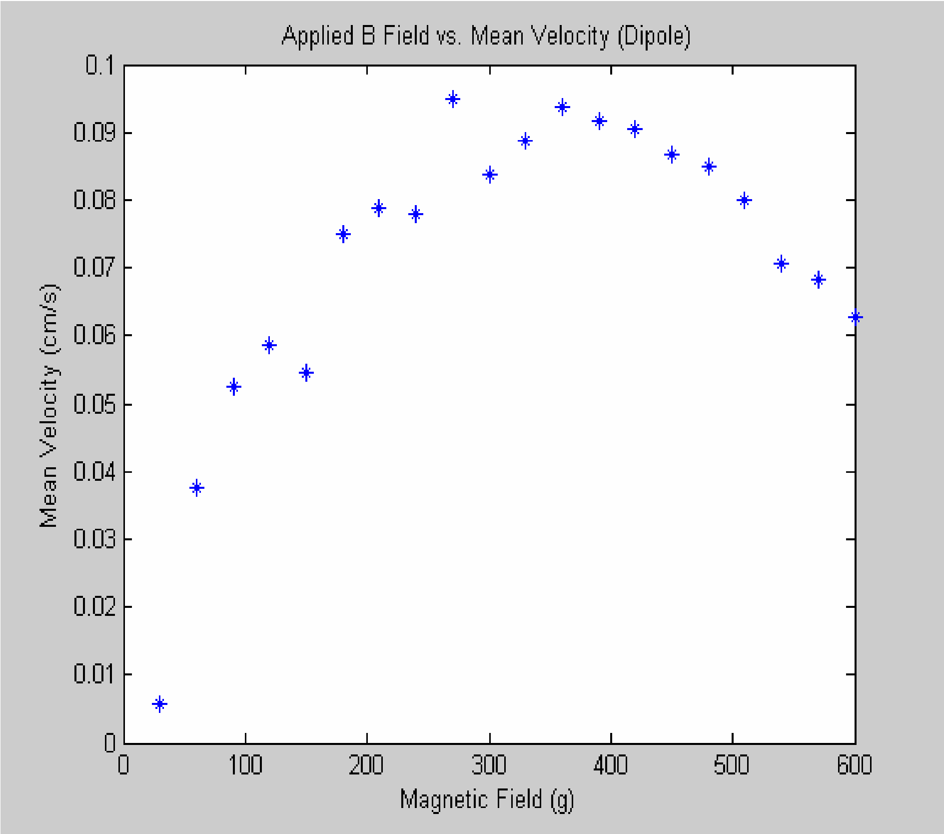
$\vec{u}$ (Ultrasound Velocimetry):



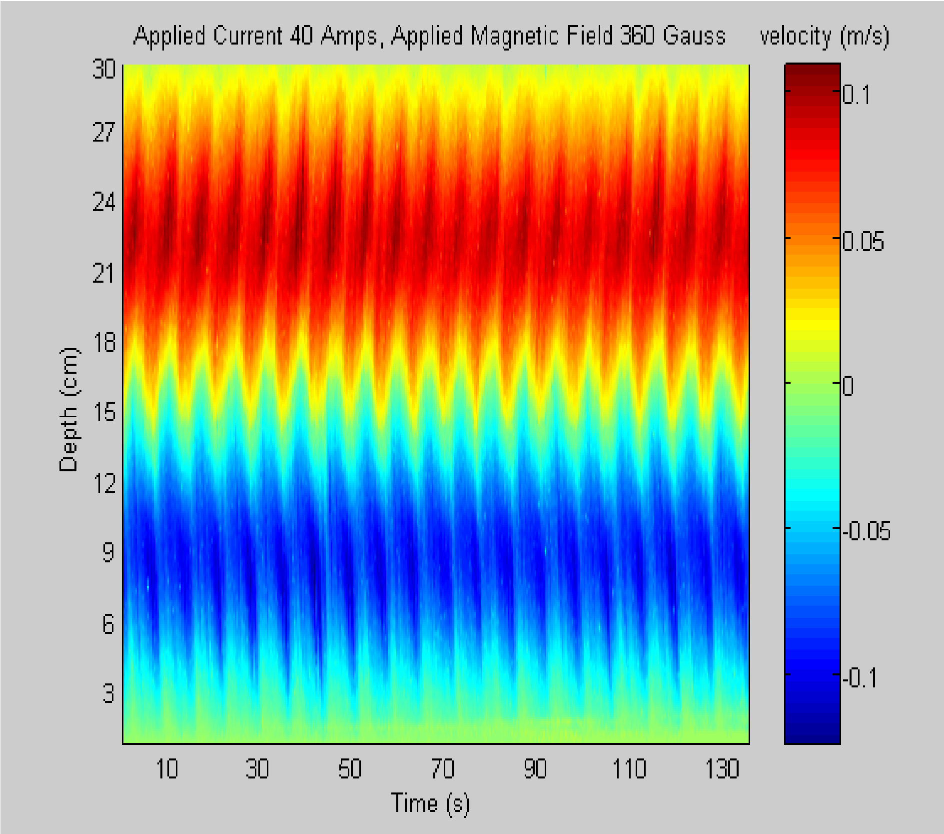
- Received echo Doppler shifted
- $\boldsymbol{f_d = 2f_0(v/c)}$, where $\boldsymbol{f_d}$ = Doppler-shifted frequency, $\boldsymbol{v}$ = velocity, $\boldsymbol{c}$ = speed of sound, $\boldsymbol{f_0}$ = transmitting frequency
- If $\boldsymbol{t}$, $\boldsymbol{f_d}$ measured can calculate position and velocity of particle

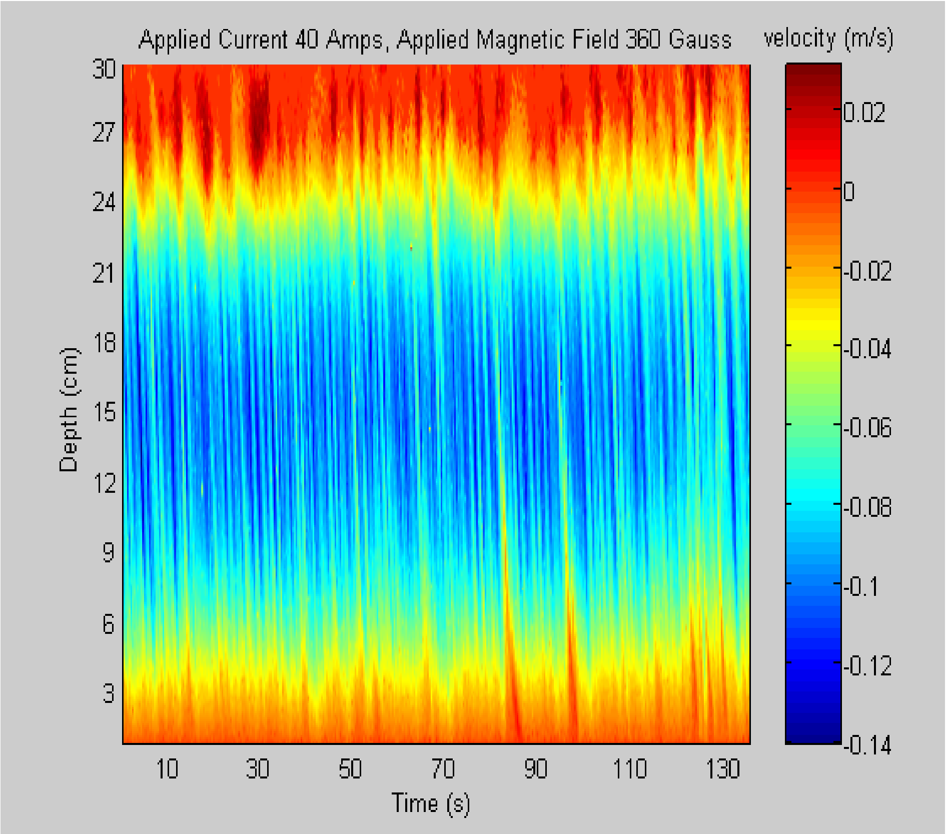
Results


Applied Current vs. Mean Velocity (Quadrupole)
Mean Velocity (cm/s)
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
10
20
30
40
50
60
70
80
Current (A)


Applied B Field vs. Mean Velocity (Dipole)
Mean Velocity (cm/s)
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.1
0
100
200
300
400
500
600
Magnetic Field (g)

Results


Applied Current 40 Amps, Applied Magnetic Field 360 Gauss
velocity (m/s)
Depth (cm)
Time (s)
30
27
24
21
18
15
12
9
6
3
10 30 50 70 90 110 130
0.1
0.05
0
-0.05
-0.1


Applied Current 40 Amps, Applied Magnetic Field 360 Gauss
velocity (m/s)
Depth (cm)
Time (s)
30
27
24
21
18
15
12
9
6
3
10 30 50 70 90 110 130
0.02
0
-0.02
-0.04
-0.06
-0.08
-0.1
-0.12
-0.14

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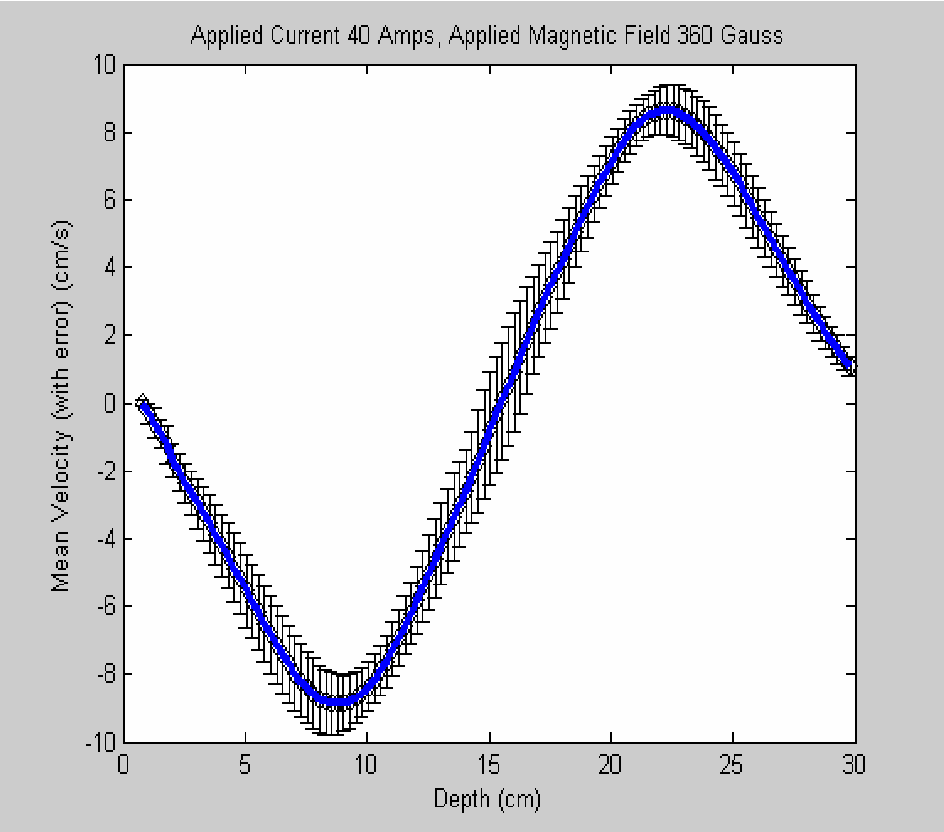
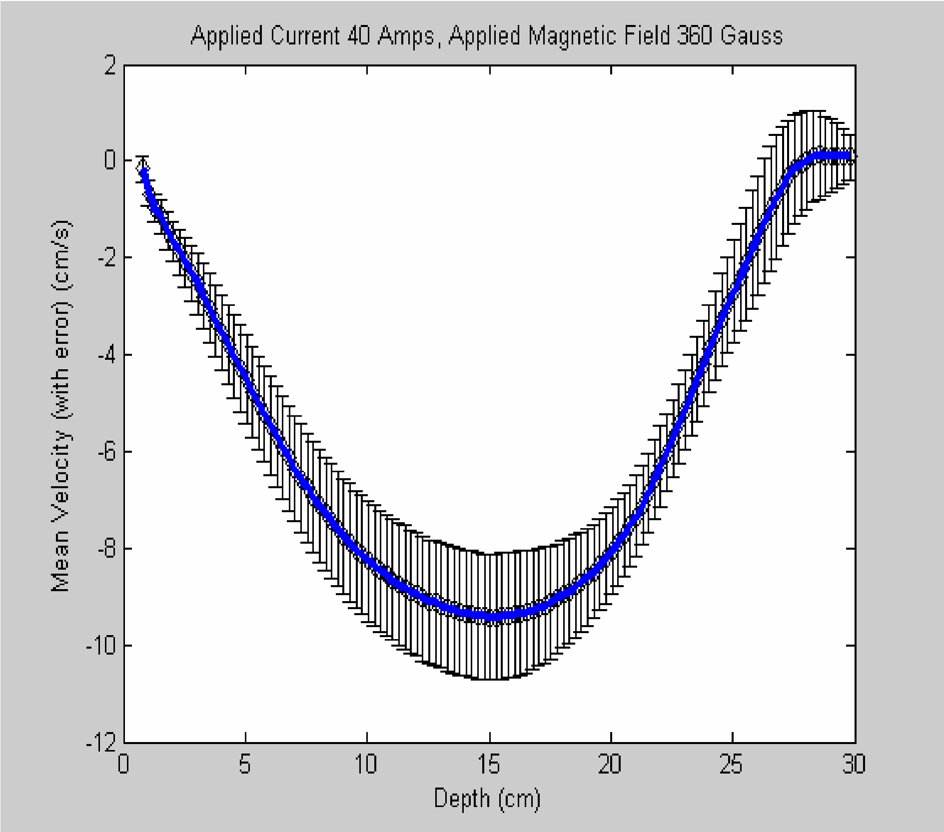
Results





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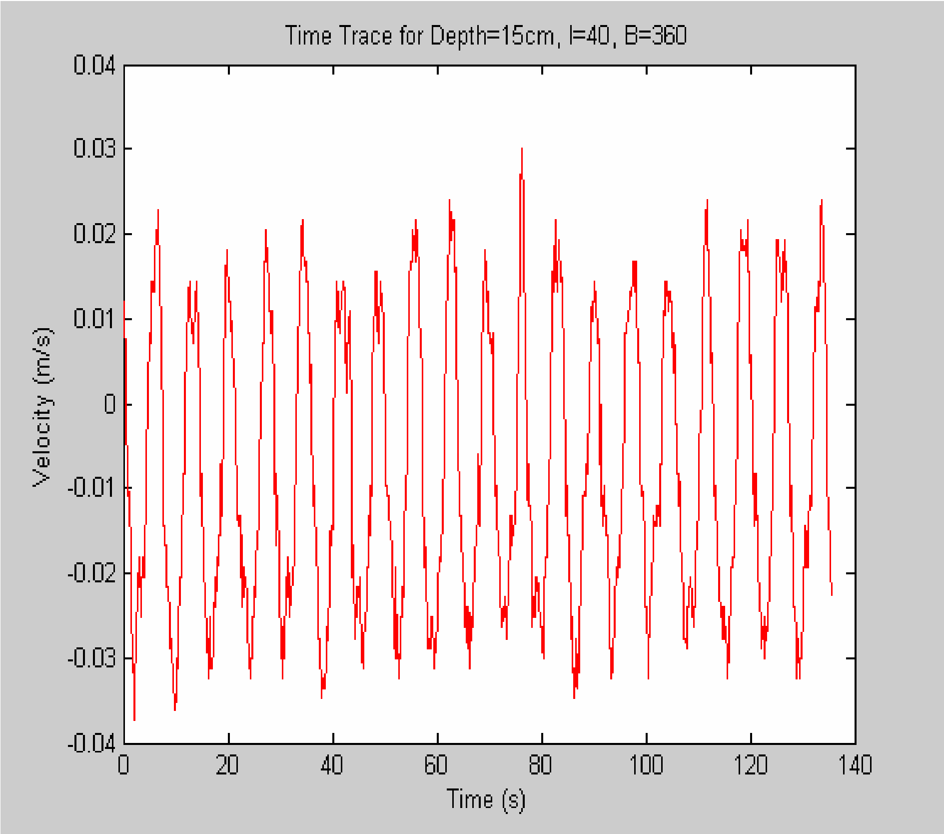

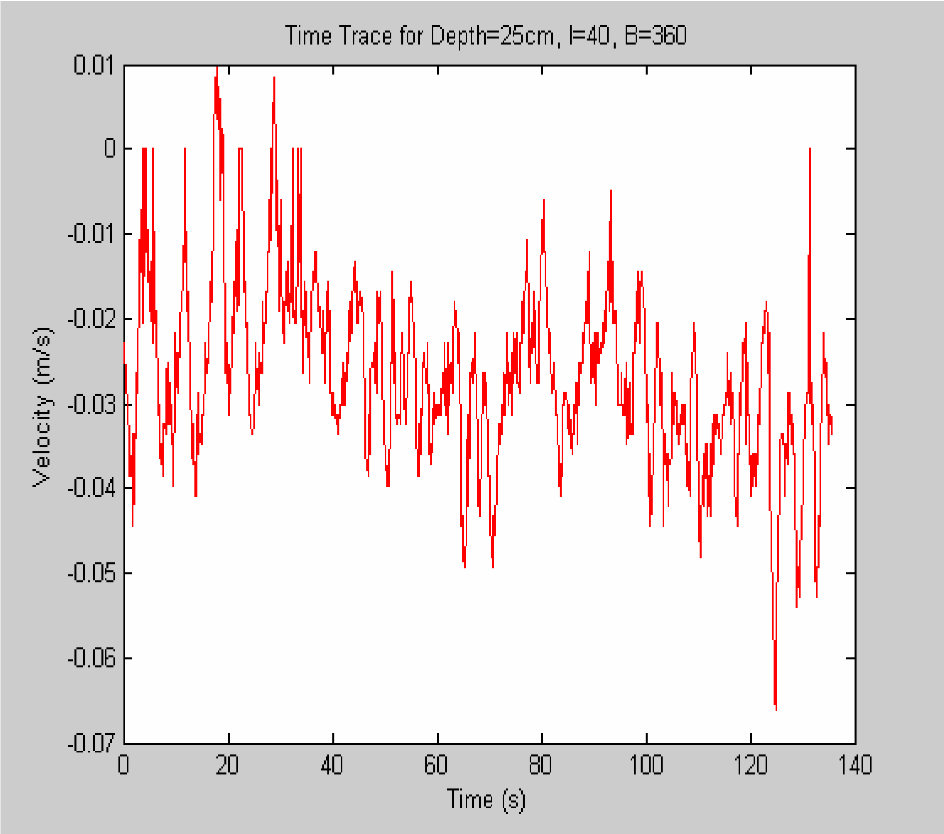

Future Work:

- complete analysis of data
- comparisons of local power input with global power input measurements made in air and water flows
- comparisons with numerical data on power fluctuations in turbulent flows
- eventual cylindrical Couette liquid sodium experiment in presence of $\vec{B}$